Air Pollution

INTRODUCTION

- Americans make the equivalent of _____________ round trips to the moon each year in their automobiles.
- The number of bicycle riders passing through a busy intersection in New York City is 173/h, and in Tianjin, P.R.C. the number is ______________________/h.
- In the next 14 years the number of automobiles in China is estimated to increase ______-fold.
- In 1994 there were almost 9,000 vehicles registered in the U.S. that burn alternative fuels. That is currently estimated as ____________
- ________________% of Americans drive to work alone.
- the average American male devotes _________ hours each year to driving and tending to his car.
- _______________ gallons of gasoline are consumed by automobiles in the U.S. every minute.
- trains can transport cargo ___________ times further than truck per gallon of gasoline used.
- plants release more isoprene into the air than any other compound, with total global discharge estimated at over ____________ tons each year.
- Burning c____________, particularly the scented and slow-burning types, may release lead, mercury and other toxins into the air.

Catastrophic events:

Meuse Valley, Belgium, 1930 – zinc smelters, 60 deaths
Donora, Pennsylvania, 1948 – 23 deaths over Halloween weekend
London, England, 1952 – 4000 deaths




Primary Standards - to protect p___________ h________ with an adequate margin of safety
Secondary Standards - to protect public w_________________ (plants, animals, and property)
Primary pollutant - discharged d_________ into the atmosphere (e.g., automobile exhaust)
Secondary pollutant - f______________ in the atmosphere through a variety of chemical reactions (e.g., p_________________ s____________)
Stationary Sources - Contribute approximately 40% of total air pollution (98% of SO_X, 95% of particulates, 56% of total hydrocarbons, 53% of NO_X, and 22% of CO)
Mobile Sources - Contribute approximately 60% of total air pollution (78% of CO, 47% of NO_X, 44% of total hydrocarbons, 5% of particulates, and 2% of SO_X)

Comparison of Nationwide Emissions From 1978 to 1991
(Values in millions of metric tons/yr)

Source Category	PM_{10}		SO_X		NO_X		CO		VOCs	
	'78	'91	'78	'91	'78	'91	'78	'91	'78	'91
Stationary Comb.	4.2	1.1	24.4	16.6	14.2	10.6	1.3	4.67	0.3	0.67
Mobile Sources	1.4	1.51	0.9	0.99	10.4	7.26	94.2	43.5	11.8	5.08
Industrial	6.8	1.84	4.5	3.16	0.9	0.6	8.4	4.69	15.0	7.86
Solid Waste	0.6	0.26	0	0.02	0.1	0.1	3.0	2.06	0.9	0.69
Miscellaneous	0.8	0.73	0	0.01	0.1	0.21	5.6	7.18	2.6	2.59
Total	13.8	5.44	29.8	20.8	25.7	18.8	112.5	62.1	30.6	16.9
Reduction (%)	60.6		30.2		26.8		44.8		44.8	

Effects of air pollution

1. Damage to h_____________ h_____________ and w_____________
2. Damage to v_____________ and a_____________
3. Damage to m_____________ and s_____________
    a.
    b.
    c.
    d.
    e.
4. Damage to the a_____________, s_____________, and w_____________

1990 Clean Air Act – provided comprehensive legislation for the protection of air quality, in addition to air quality and emissions standards, the 1990 CAA:

– established a permit program for large sources
– increased EPA's enforcement abilities
– established deadlines for filing permit applications and meeting the standards
– allows for public participation in the promulgation of standards
– encourages market forces in the meeting of air quality standards to encourage least cost solutions

Additional definitions:

c__________ pollutant – pollutant that is regulated based on health or environmental criteria

NAAQS - National A_______________ A_______ Quality Standards - revised in 1987, set air quality standards.

SIP – State I_________________ Plan to achieve air quality standard, each State must prepare, if it is not acceptable, EPA can take over the air quality enforcement in that State.

AQR – Air Q__________ R_________________ – areas that have air quality that meets primary standards is classified as an attainment area, if not, then it's a non-attainment area.

NESHAPs – National E____________ Standards for H___________ Air P______________

MACT – Maximum Achievable C________________ T_________________ (also BACT – best available control technology) – the best available control equipment that is technologically feasible and is currently available.

NSPS – New S_____________ P_________________ Standards

Air Pollution Calculations

Ideal Gas Law

$$PV = nRT \tag{1}$$

where
P = absolute pressure, Pa
V = volume of n moles of gas
R = universal gas constant, 8.3143 J/K·mole = 8.3143 Pa·m^3/K·mole
T = absolute temperature, K

The Ideal Gas Law can be rewritten as follows:

$$V = nRT/P \tag{2}$$

or

$$V/n = RT/P \tag{3}$$

which can also be expressed as

$$MW/\rho = RT/P \tag{4}$$

where
MW = the molecular weight, g/mole
ρ = density, g/m^3

Example Problem.

Find the density of O_2 at 273 K and 98,000 Pa.

rearranging equation (4) above: $\rho = MW \cdot P/RT$
$= (32\text{g/mole} \cdot 98{,}000\text{Pa})/(8.3143\ \text{Pa} \cdot \text{m}^3/\text{K} \cdot \text{mole} \cdot 273\text{K})$
$= 1{,}382\ \text{g/m}^3$

Example Problem.

Find the volume occupied by 5.2 kg of CO_2 at 152 kPa and 315 K.

$$V = nRT/P$$

The number of moles = 5200g/(44 g/mole) = 118.2

$$V = (118.2 \text{ moles} \cdot 8.3143 \text{ Pa·m}^3\text{/K·mole·315 K})/152{,}000 \text{ Pa}$$
$$= 2.036 \text{ m}^3$$

Converting ppm

When ppm is used in the context of air pollution it is in terms of parts per million on a volume basis (whereas ppm in water and wastewater refers to a weight basis). It is a convenient measure in that the volume of a pollutant with respect to the total volume will not change with temperature and pressure. To convert to μg/m^3 we will use the Ideal Gas Law.

Example Problem.

Convert 80 μg/m^3 of SO_2 to ppm at 25°C at 101.325 kPa.

Use a basis of 1 m^3 :

$$V = nRT/P$$
$$n = 80 \text{ μg/(64 g/mole)} = 1.25 \cdot 10^{-6} \text{ mole}$$
$$V = (1.25 \cdot 10^{-6} \text{ g} \cdot (8.3143 \text{ Pa·m}^3\text{/K·mole}) \cdot 298 \text{ K})/101{,}325 \text{ Pa}$$
$$= 0.03056 \cdot 10^{-6} \text{ m}^3$$
$$= 0.03056 \text{ ppm}$$

Note: simplification of this calculation gives the following conversions:

at 25°C multiply μg/m^3 by 0.02445/M.W. to give ppm
at 20°C multiply μg/m^3 by 0.02404/M.W. to give ppm

Partial Pressures

The Law of Partial Pressures (or Dalton's Law) states that the total pressure exerted by a mixture of gases is equal to the sum of pressures exerted by each individual gas:

$$P_T = P_1 + P_2 + P_3 + ...+ P_n$$

$$= n_1RT/V + n_2RT/V + n_3RT/V + ...+ n_nRT/V$$

$$= (n_1 + n_2 + n_3 + ...+ n_n)RT/V$$